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FINAL REPORT

19990071

**NORTHERN VIGOUR OF STRAWBERRY
CROWNS-IMPROVING CROWN YIELD FOR
LOCAL AND FOREIGN MARKETS**

**Funded by:
The Agriculture Development Fund**

**February 2004
Prepared by: University of Saskatchewan**

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**“Northern Vigour® of Strawberry Crowns – Improving
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Final Report

January, 2004

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ABSTRACT

Increasing the yield of strawberry crowns appears to be the critical limitation to commercial crown production in Saskatchewan (Storey & Lokken, 1999). This project examines methods to cost-effectively increase strawberry crown yields in 'Camarosa' for the California market 'Sweet Charlie' for the Florida market and 'Totem' and 'Kent' for the domestic market. Results suggest that using a fertility regime of 200 lbs./ac of nitrogen, using floating row covers of material such as Remay, use of overwintered mother crowns, planting spring plug plants based on tissue cultured plantlets are all positive methods to increase the number of daughter plants. Regular greenhouse plug production may be another option for both Saskatchewan spring planting material and as an alternative to bare-root field crowns for export in the fall to California. Hormonal dips of BAP and the use of Treflan seem to be detrimental to daughter formation, while fumigation has no effect on the number of daughters produced.

EXECUTIVE SUMMARY

The production advantages of vegetatively propagated crops such as potatoes grown in northern regions compared to southern sources has long been recognized by potato growers in Europe and North America. Saskatchewan's unique climate of long days, cool nights during the growing season along with a disease-free environment provides an opportunity to produce superior plant material. This phenomenon has already been established in Saskatchewan-grown seed potatoes and is termed "Northern Vigour[®]". It has resulted in significant export of seed potatoes and domestic production of this crop. Over the past 7 years, our results on strawberry, garlic and medicinal plants show potential to develop Saskatchewan as a supplier of high quality, superior planting material. Saskatchewan grown crowns have produced higher early fruit yields (40-60% over California-grown crowns). The market potential is promising where California annually plants 750 million crowns (\$35 US million). Californian commercial growers

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are keenly interested in testing and accessing new markets since there is an increased push for earlier yields. Markets also exist for Florida ('Sweet Charlie') and domestic crown sales ('Kent' in Saskatchewan, 'Totem' in B.C.) and therefore, 4 cultivars were tested in this project. To create a viable industry, crown yield must be increased. The minimum crown yield required to make a profit is 8 daughter crowns per mother and returns significantly increase with each additional daughter/mother produced. To increase daughter crown yield, the following treatments were tested: crown yields under Remy field cover, crown yields after a hormonal application under tissue culture and crown dip treatments, one year versus a two year production cycle, the effect of fertility on runner and crown production, herbicide trial and fumigation trial. In addition, while not formerly part of the original proposal, greenhouse plug production was added. Greenhouse-produced plug plants command a 3 fold premium price compared to bare-root field plants and fit into the scheduling of the greenhouse growers in Saskatchewan.

'Camarosa' crowns grown under Remy produced a greater number marketable crowns (12 daughters/mother) compared to control on bare ground (8 daughters/mother) and compared to 'Kent', 'Totem', and 'Sweet Charlie'. However, all cultivars increased numbers of rooted marketable, unrooted marketable and total daughters under the Remy treatment. Without the use of Remy, 'Kent' produced equivalent number of daughter crowns as 'Camarosa'. Fruit yield in California based on 'Camarosa' daughter plants produced with and without Remy showed Remy reduced fruit yield. Remy field cover was not removed until August 22 and the prolonged higher temperatures may have reduced chilling accumulation and florigenesis. If Remy can continue to be used, earlier removal is recommended.

No significant differences were detected between tissue cultured plants treated to various concentrations of BAP. Thus, there was likely significant carry-over of endogenous BAP content within these plantlets. The daughters per mother produced based on plug plants originating one generation from tissue cultured material with no hormones had on average 28 daughters produced in the first season. This is considerably higher than yield based on field-grown bare root mother plants many generations removed from tissue culture (8 daughters). In future, greenhouse grown-plug plants which are active and also many generations away from tissue culture should be tested as

an alternative to planting bare-root mother crowns in the spring. This may potentially increase subsequent daughter crown yields under field conditions.

Crowns treated to a BAP dip for 10 seconds proved to have negative affect on daughter formation and overall plant vigour. For the fertility trial, 250lbs./ac of nitrogen produced significantly fewer daughter crowns, while other treatments of 100, 150 and 200 lbs./ac expressed no significant differences. The CV% were quite high in this study and the 200 lbs./ac treatment generally produced higher numbers of daughter crowns. Daughters from year one allowed to over-winter for a second season produced more daughters than newly planted mother crowns in the spring. Based on another ADF final report (Tom Ward, ADF # 97281), 'Camarosa' fruit has moderate potential as a fruiting cultivar and thus growers might have the option of diversifying their market by selling both fruit (summer) and crowns (fall) from the same plant. Treflan herbicide had mixed effects on the crowns both enhancing and decreasing daughter crown yield in 2 consecutive seasons. The fumigation study produced no significant differences in daughter crown production between the control and treatment with Basmid.

In summary, increasing daughter crown yield beyond 8 crowns per mother should not be a significant problem in future. Methods include: producing daughters from overwintered mother plants (2nd year daughters), planting bare-root field-grown crowns as early as possible in the spring (April), or planting in May but using greenhouse-grown plug plants, using Remy field cover in the first season for the first 2 months, increasing the soil nitrogen to 200 lbs./acre all increase daughter crown numbers. In future, testing should be performed on fall-planted bareroot strawberry crowns and using registered greenhouse-grown plug plants in spring planting.

TECHNICAL REPORT

I) Utilization of Mulch & Field Cover Regimes

1) Remay, Black Plastic mulch study, 2000.

The objective of this study was to increase the temperature around the strawberry crowns by creating a microclimate to promote plant runnering. One possible method of increasing the temperature around the crown is to utilize black plastic mulch. Black mulch has been proven to increase the air temperature above the plastic by +5°C, while clear and white plastics only create a 1°C difference from bare soil temperatures (Tarara, 2000). Remay was also tested. It is a translucent spun-bonded polyester used as a field cover for horticulture crops to increase air and soil temperatures. Bare soil served as the control.

This study was conducted at a site south of Saskatoon (Lat. 52° 07'N, courtesy of Dr. Karen Tanino, Saskatoon, SK.). Two mulch and field cover regimes were tested: black plastic mulch, reemay cover and a control of bare soil. Each treatment consists of four replicates with ten plants per replicate. Before the crop was established, soil samples were taken to determine the N,P,K and S status. Soil analysis indicated that the texture of the soil is loamy sand with a pH of 7.6, and was deficient in NO₃-N, and P with marginal amounts of SO₄-S. To improve soil fertility, 100lb/ac of nitrogen and phosphorous were applied with 22 lb/ac of sulfur, to bring the total available fertility up to 125lbs/ac of nitrogen, 135lbs/ac of phosphorous and 42lbs/ac of sulphur. Planting occurred for all treatments on May 17th, 2000.

a) Black Plastic Mulch

Each replicate consisted of single lengths of 3m long drip tape laid along the ground and secured with large staples. Mulch was then rolled over the top of the drip tape with the edges pulled tight and dug into the ground to form a snug ground cover. Ten holes were cut into the plastic every 30cm staggered on either side of the drip tape and planted with

one crown per opening. Plants were watered as necessary. To encourage runner and crown production, flower buds were removed periodically.

b) Remay

Ten plants per replicate were planted at 30cm inter-row spacing. The replicates were then covered with translucent spun-bonded polyester (Remay) with all edges tightly dug in to form a secure covering. Watering was accomplished through over head sprinklers as required. To encourage runner and crown production, flower buds were removed periodically.

c) Control

The control consisted of ten plants per replicate planted into bare ground. Watering was accomplished via overhead sprinklers. To encourage runner and crown production, flower buds were removed periodically.

Data loggers were placed within the trial to take readings of the soil and air temperatures of each treatment at hourly intervals. Data collection consisted of the number of rooted and unrooted daughters produced within each replicate along with the corresponding soil and air temperatures.

Results

Harvesting occurred on the 29th of September 2000. Plants were dug using a small-modified potato harvester, placed into large plastic garbage bags and taken to the Plant Sciences Field Lab for data collection. Plants were counted into two groups, number of rooted and unrooted plants (Table 1.1).

No statistical differences were found between the number of rooted crowns and total number of daughters per mother produced between the three treatments. Visual inspections in the field suggest that differences should have existed between these two treatments. Plants under the remay (Figure 1.1) tended to produce more daughter plants in terms of the number rooted and overall daughter production. Plants grown in the black plastic mulch (Figure 1.2) should have had a low number of rooted as the mulch acted as a physical barrier in the number which could actually be set. Plants grown under control

conditions (Figure 1.3) had even fewer runners and daughters produced than the plastic mulch and Remay. A statistical significance may not have been noted due to the variation noted within the original data. Mulch and row cover treatments were disbursed over a field, which had wide variations in soil texture. The soil ranges from sand to a loam with the percentage of organic matter decreasing from 0.7 to 2.4% respectively. Strawberry crowns grown in areas which had a sandy texture were small and lacked runnering, while plants in the loamy areas of the field had increased crown survival and produced larger more vigorous plants.

Statistical differences were noted however between the number of unrooted daughters per mother. The black mulch had significantly higher daughters, which were unrooted. The plastic mulch used was laid in a 0.6m width. Due to the distance the runners would have to grow before the plastic barrier was avoided, many of the daughters were left growing on top of the mulch causing no rooting to occur. The CV% is 45.76, which is quite high. This could account for the variability noticed within the field due to drastic changes of the soil textures.

Table 1.1. Comparison of the number of daughters produced under black plastic mulch and Remy systems and control.

Treatments	# Rooted / Mother	# Unrooted/Mother	Total Daughters/Mother
<i>Remy</i>	4.32	2.68	7.00
<i>Black Plastic</i>	0.92	5.85	6.77
<i>Control (open ground)</i>	1.36	2.59	3.95
<i>Statistical Significance</i>	ns	*	ns
<i>Lsd</i>		2.71	
<i>CV%</i>	104%	45.76%	60.50%



Figure 1.1 'Camarosa' strawberry plants grown under Remy, 2000.

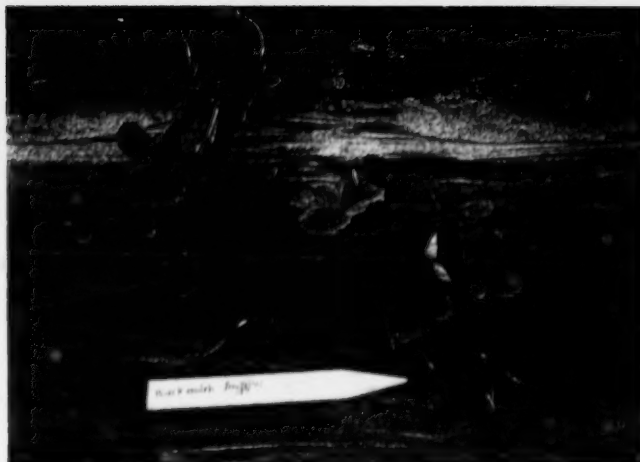


Figure 1.2 'Camarosa' strawberry plants grown under black plastic mulch.



Figure 1.3 'Camarosa' strawberry plants grown under bare ground (control) conditions.

2) Remay mulch study, 2001

In 2000, no statistical differences were found between the number of rooted crowns and total number of daughters per mother produced among the three treatments (no mulch, black plastic and Remay). However, the variation within the data was extremely high (CV 104%). Soil texture had varied markedly across the field. Texture ranged from a sandy loam to a loam with the organic matter content ranging from 0.7 to 2.4%. Strawberry crowns grown in areas that had more sandy texture were small and lacked runners, while plants in the loamy areas of the field had higher crown survival and produced larger more vigorous plants. Visual inspections in the field suggested significant differences should have existed between treatments. Although not statistically significant, plants grown under the Remay produced a greater number of mean rooted and total number of daughter plants per mother. The black plastic mulch treatment applied in 2000 reduced the number of rooted daughter crowns compared to the Remay treatment. Thus, the 2001 study focused on Remay field cover versus a bare ground control. Research conducted by Fernandez (2001) suggested that an increase in the daily temperatures occurs under rowcovers and thus can lead to the increase in fruit yield of strawberry plants. We are extending this research to determine if the rowcover Remay can increase the runnering and daughter production of strawberry plants in our climate.

This study was conducted at Outlook, Saskatchewan (Lat. 51° 30'N) Saskatchewan Irrigation Development Centre (SIDC). Four cultivars were tested, 'Camarosa' for the Californian market, 'Sweet Charlie' for the Florida market and 'Totem' and 'Kent' for the domestic market. Each cultivar had two treatments consisting of Remay versus a control of bare soil. Each treatment consisted of six replicates of twenty plants each. Before the crop was established, soil samples were taken to determine the N,P,K and S status. Soil analysis indicated that the texture of the soil was a loam with a pH of 8.0 to 8.2. The soil was deficient in NO₃-N, and P. To improve soil fertility, 100lb/ac of nitrogen and phosphorous were applied with 22 lb/ac of sulfur, to bring the total available fertility up to 125lbs/ac of nitrogen and 135lbs/ac of phosphorous. Planting occurred for all treatments on May 29th 2001 utilizing a split plot design. Field covers were removed August 22, 2001 to allow chilling to occur within the crowns. Daughter crowns produced

under both Remay and control treatments were then sent to California for subsequent fruit yield evaluation.

a) Remay

Twenty plants per replicate were planted at 30cm inter-row spacing and 100cm between row spacing. The replicates were then covered with translucent spun-bonded polyester (Remay) with all edges tightly dug in to form a secure covering as in 2000 (Figure 1.1). Watering was accomplished through over head sprinklers as required. To encourage runner and crown production, flower buds were removed periodically when the covers were removed for weeding.

b) Control

The control consisted of twenty plants per replicate planted into bare ground. Watering was accomplished by utilizing overhead sprinklers. To encourage runner and crown production, flower buds were removed periodically.

Data loggers were placed within the trial to take readings of the soil and air temperatures of each treatment at hourly intervals. Soil probes were placed approximately 7.5 cm below the soil surface while air probes were recording temperatures at the crown level. Data collection consisted of the number of mother crowns which survived the planting process one month post-planting and the number of rooted and unrooted daughters produced within each replicate along with the corresponding soil and air temperatures.

Results

Harvesting occurred on September 25th, 2001. Plants were dug using a small-modified potato harvester and then placed into large plastic garbage bags and taken to the Horticulture Field Lab for processing at the University of Saskatchewan. Plants were counted into three groups; number of marketable daughters, daughters of marketable size but no root structure and unrooted daughters (Table 1.2). Data was analyzed using a split plot design.

Table 1.2. Effect of Remy on daughter production in 'Camarosa', 'Totem', 'Kent' and 'Sweet Charlie' strawberry crowns in 2001.

Cultivar	Treatments	Marketable Daughters	Marketable Size without roots	Unrooted Daughters	Total Daughters	Total Daughters/Mother
<i>Camarosa</i>	<i>Remy</i>	93.67	61.88	35.58	194.13	12.24
	<i>Control</i>	55.34	36.38	36.58	128.29	8.51
<i>Totem</i>	<i>Remy</i>	41.97	35.99	31.61	109.57	7.48
	<i>Control</i>	37.60	22.17	18.03	77.80	5.28
<i>Kent</i>	<i>Remy</i>	59.95	43.45	38.24	141.64	9.63
	<i>Control</i>	53.13	43.64	31.17	127.94	8.42
<i>Sweet Charlie</i>	<i>Remy</i>	52.31	26.01	34.21	112.53	7.64
	<i>Control</i>	48.04 **	27.32 **	26.75 ns	102.10 *	6.69 ns
	LSD	6.20	13.19	-	28.49	-
	CV%	18.58%	29.43%	35.45%	18.97%	19.30%

- ns is no significance; * and ** = $p \leq 0.05$ and $p \leq 0.01$, respectively

*Averages are based on the number of surviving mothers.

Under the Remy treatment 'Camarosa' produced significantly higher numbers of marketable daughters with and without roots compared to the 'Totem', 'Kent' and 'Sweet Charlie' under the Remy treatment. Without Remy, 'Kent' produced as many daughter crowns as 'Camarosa'. The high CV % is due to the variation in the field. This study was unknowingly planted over an area, which had portions of weed control and no weed control the prior season. This led to some of the replicates being planted in higher weed populations than other replicates. Previous research conducted by Pritts *et al.* (2001) suggests that newly planted strawberries are the most susceptible to weed competition during the first two months after planting. Although hand weeding occurred on a weekly

basis, weed populations were still higher in certain field regions. This could have attributed to the variation within the data.

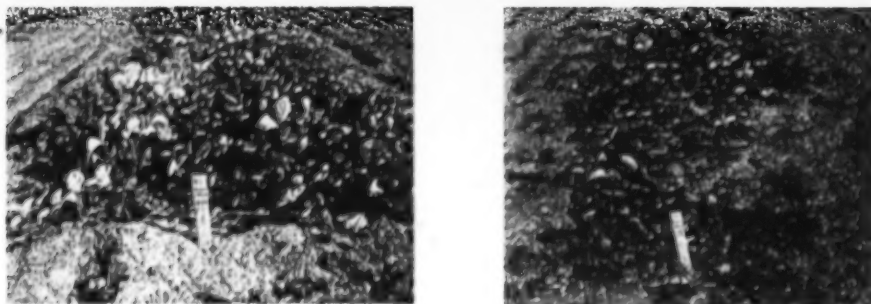


Figure 1.4 'Kent' under mulch (left) and no mulch (right) treatments.

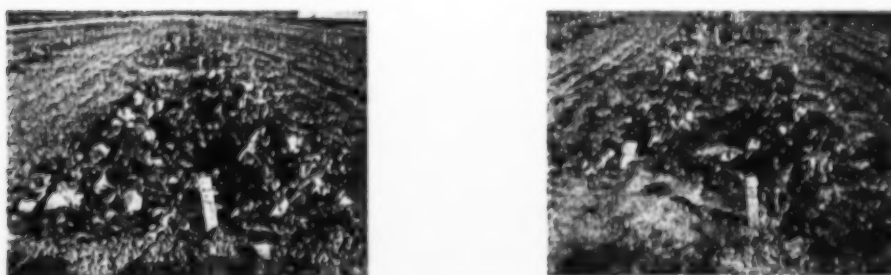


Figure 1.5 'Sweet Charlie' under mulch (left) and no mulch (right) treatments.



Figure 1.6 'Totem' under mulch (left) and no mulch (right) treatments.



Figure 1.7 'Camarosa' under mulch (left) and no mulch (right) treatments.

The Remy treatment for all cultivars had a positive effect on the marketable number of daughters as well as overall number of daughter produced. Thus, the use of Remy covers may enhance runner formation and subsequent daughter production (Figures 1.4 -1.7).

Temperature is one of the important factors in plant growth and development. With strawberries, an increase in temperature facilitates runnering and thus the number of daughters produced. The soil and air temperatures were taken at 7.5 cm below the soil surface and at crown level respectively for each of the treatments from time of planting until August 22nd (when the covers were removed to allow for chilling to occur). The daily mean temperatures under the Remy were up to 3°C higher than the control treatment (Appendix figures A1-A6) and had a more pronounced effect in increasing soil temperatures. Remy generally increased soil and air temperatures by an average of 2.5°C and 1.5°C, respectively. The enhanced soil temperatures may have induced the higher rooted daughters observed under Remy, while the higher air temperatures are expected to increase runnering and daughter numbers. It is unknown why the control soil temperatures were above the Remy from July 1st to July 18th. It is possible that a tear could have occurred in the Remy near the sensor since a herd of deer had gone through the plot ripping holes in the Remy covers. This could have caused the soil temperatures to decrease, as the heat would then escape instead of being held in by the covering material. Note: since that time, Bill and Jean King (Outlook) have erected an 8 foot game fence around their production area.

Table 1.3. 'Camarosa' fruit production in 2002 based on 2001-produced strawberry crowns from Remy treatments compared with controls (without Remy)

Fruit Production Year		Source of Crowns	Marketable Yield kg/ha (lbs/acre)			
California	Location of Fruit Production		Jan. + Feb.	+/- %	Total	+/- %
2002	B&E Farms, Orange County, CA	Lassen Canyon, CA	7,373 (6,564)		9,124*** (8,124)	
		Outlook, SK (with Remy)	4,571 (4,070)	- 61.3%	4,963 (4,419)	-45.6%
		Outlook, SK (no Remy)	8,619 (7,674)	+16.9 %	8,358 (7,442)	-8.4%

+/- represents the percentage above or below California-sourced crowns.

Although daughter yield increased under Remy (Table 1.2), subsequent fruit yield in California was reduced (Table 1.3). Both early and final fruit yields were reduced compared to bare ground (without Remy) as well as California-sourced crowns (Lassen Canyon). This may be due to the warmer temperatures under the Remy covers (Figs. 1.8 – 1.13) preventing both chilling requirement accumulation and flower bud initiation (high day/night temperature differences can by-pass the short photoperiod requirement for florigenesis). If Remy can continue to be used effectively, it is recommended that it be removed earlier than August 22---potentially as early as July, depending upon runner and daughter crown production during the season.

II) Tissue Culture of 'Camarosa' Strawberry Crowns

Tissue culture is a vegetative propagation method extensively used in most horticultural crops to obtain virus-free initial material for further multiplication. Previous studies conducted by Lopez-Aranda *et al.* (1994) and Merkle (1993) indicate addition of cytokinins to tissue culture medium can significantly increase both strawberry runner and crown production when grown under both greenhouse and field conditions. This beneficial effect of cytokinins may be utilized as a means to enhance crown production under field conditions. As an initial step, this study was established to evaluate the effect of cytokinins added to the tissue medium on the runner and crown production of the subsequent generation of strawberry crowns grown in field conditions.

Various treatment rates of BAP (benzylaminopurine, Sigma Chem. Co., St. Louis, MO, U.S.A.) included 1mg/L, 0.25mg/L, 0.5mg/L, 0.0mg/L BAP (control) and charcoal in MS media. BAP was applied to the strawberry tissue culture media in early April 2001. By mid-May 2001, the 'Camarosa' strawberry plantlets were removed from culture and planted into small plug trays containing SunShine Mix #5 (Sungro Horticulture Products, Bellingham, WA) growing media. The trays were placed in a mist chamber for two weeks to enhance rooting. Once rooting occurred, the plants were placed in the greenhouse ($600\text{-}700\mu\text{mol m}^{-2}\text{s}^{-1}$ and $25/18\text{ }^{\circ}\text{C}$ day/night). Plants were fertilized once a week with five hundred ppm (500mg/L) solution of 20:20:20 (N:P₂O₅:K₂O) plus micronutrients. Once the roots had established, the strawberry plants were placed outside to harden off for a two-week duration.

1) Year 2000 study: Pike Lake location

BAP was applied to the strawberry tissue culture media on the 7th of March, 2000. On April 10th, 2000, the strawberries were removed from culture and planted into a small plug tray containing SunShine Mix #5 (Sungro Horticulture Products, Bellingham, WA) growing media. The tray was placed in a mist chamber for two weeks to enhance rooting. Once rooting occurred, the plants were placed in the greenhouse ($600\text{-}700\mu\text{mol}$.

$\text{m}^{-2}.\text{s}^{-1}$ and 25/18 °C day/night). Plants were fertilized once a week with five hundred ppm (500mg/L) solution of 20:20:20 (N:P:K). Once the roots had established, the strawberry plants were transplanted into 4" pots and placed back into the greenhouse for further growth to occur. After two weeks, the plants were placed outside to harden off on the 19th of May, 2000.

The site was located 20 minutes south of Saskatoon near Pike Lake, Saskatchewan. Before the crop was established, soil samples were taken to determine the N,P,K and S status. Soil analysis indicated that the soil was marginal in $\text{NO}_3\text{-N}$ and deficient in P_2O_5 . Nitrogen and phosphorous were added for an overall soil nutrient availability to 120lbs/ac of each nutrient. Planting occurred on the 26th of May, 2000. Plants were watered on a regular watering regime utilizing an overhead watering system on a pivot. To encourage runner and crown production, flower buds were removed periodically. The treatment effect on crown production was evaluated by determining the number of runners per plant and rooted and unrooted crowns per plant at time of harvest.

Results

Preliminary data collected on the 26th of September, 2000 showed 1 mg/L BAP enhanced the number of rooted daughter crowns compared to control treatments (Table 2.1). However, due to the increased number of unrooted daughters, total numbers of daughters were higher under control. For the crown industry, number of rooted crowns is an important criterion since unrooted daughters would have to be hand-set to induce rooting.

Table 2.1. Effect of BAP on daughter production in 'Camarosa' strawberry crowns.

Treatments	# Rooted daughters	# Unrooted daughters	Total # Daughters	# total daughters/ mother
<i>Control</i>	68	73	141	28.2
<i>0.25mg/L</i>	76	48	124	24.8
<i>0.5mg/L</i>	88	39	127	25.4
<i>1mg/L</i>	101	26	127	25.4

2) 2001 study at Saskatchewan Irrigation and Diversification Centre, Outlook, SK.

This study was located at SIDC in Outlook, SK. Before the crop was established, soil samples were taken to determine the N,P,K and S status. Soil nutrient levels were increased over that of year 2000. Planting occurred on the 7th of June 2001. The experimental plot was arranged as a RCBD consisting of five treatments (1mg/L, 0.25mg/L, 0.5mg/L, no BAP (control) and charcoal in media) with five plants per replicate and four replications. Plants were watered on a regular watering regime utilizing an overhead watering system. To encourage runner and crown production, flower buds were removed periodically. The treatment effect on crown production was evaluated by determining the number of original plants that survived field planting one month post-planting and the subsequent number of rooted and unrooted crowns at the time of harvest.

Results

Harvesting occurred on the 27th of September 2001. Plants were dug using a small-modified potato harvester. Plants were then placed into large plastic garbage bags and taken to the Horticulture Field Lab for processing. Although no significant differences were noted between any of the tissue culture treatments, the total number of daughters per mother are considerably higher under tissue culture treatment than those produced by any of the other studies conducted within this report. Even the control which consisted of 'Camarosa' plants tissue cultured without any hormone application produced 28 daughters per mother (Table 2.2). However, this may also be the result of

the plants being more mature at the time of planting as the plant material was grown up in the greenhouse in plug trays prior to field planting thus providing a greater root system upon transplanting to the field. These treatments need to be compared to non-tissue cultured plant material grown in a greenhouse prior to planting as well as direct planting which is normal field practice of non-tissue cultured plant material. The CV% is quite high ranging from 22 to 30%. This is possibly due weed competition as there was a lot of variation within the field due to previous years studies that had been conducted in that area. This may have caused variances within the daughter numbers.

Table 2.2. Effect of BAP on daughter production in 'Camarosa' tissue cultured strawberry crowns.

Treatments	Marketable Daughters	Marketable Size without roots	Unrooted Daughters	Total Daughters	Total Daughters/Mother
<i>Control</i>	65.40	37.80	30.20	133.40	28.30
<i>0.25mg/L</i>	69.52	35.80	29.45	134.80	27.43
<i>0.5mg/L</i>	66.62	45.00	32.85	144.50	30.29
<i>1.0mg/L</i>	63.62	34.40	29.25	127.30	26.85
<i>Charcoal</i>	57.22	41.40	35.85	134.50	28.29
Statistical Significance	ns	ns	ns	ns	ns
LSD	-	-	-	-	-
CV%	23.89%	33.81%	30.41%	21.30%	22.07%

- ns is no significance; * and ** = $p \leq 0.05$ and $p \leq 0.01$, respectively

*Averages are based on the number of surviving mothers

III) The Influence of Hormonal Dip on Subsequent Yield

Hormonal application has had mixed results in the past. Previous work indicated root drenching produced superior yields of runners compared with foliar spray under greenhouse conditions. However, crowns dipped for 12 hours at 12.5mg/L and 25.0 mg/L of BAP (benzylaminopurine) resulted in high crown mortality rates under field conditions. Soil drenching of crowns previously tested with a rate 250mg/L of BAP did not have a significant effect on crown growth. This study was conducted using shorter dipping times than in previous studies at the non toxic levels (250mg/L) of BAP.

1) Year 2000, Pike Lake location

The site for this study is located 20 minutes south of Saskatoon near Pike Lake, Saskatchewan. Before the crop was established, soil samples were taken to determine the N,P,K and S status as previously outlined. Planting occurred on the 16th of May, 2000.

Plants were subjected to two treatments. Plants were either treated with a solution of 250mg/L of BAP (benzyladenine purine - BAP) plus a surfacant Tween 20 at 0.012% or with a control solution of distilled water and Tween 20 at 0.012%. Each treatment consisted of four replicates of five plants each. Plants were treated with either solution by dipping for a ten second duration and then immediately planted into the field. All crowns were planted using a 30cm inter-row spacing. Plants were watered on a regular watering regime utilizing an overhead watering system on a pivot. To encourage runner and crown production, flower buds were removed periodically. The treatment effect on crown production was evaluated by determining the number of runners per plant and rooted and unrooted crowns per plant at time of harvest.

Results

Data was collected on the 26th of September, 2000 at Pike Lake. Plants were dug and trimmed prior to crown counts. Since there was 100% survival, data was analyzed on a total yield basis instead of a per mother basis. Table 3.1 indicated a statistically significant difference between the number of crowns rooted. Crowns dipped in the BAP solution prior to plant produced fewer crowns than those dipped in plain water (control).

No differences were noted between the number of unrooted and total daughters. CV's % were at 49.12% for unrooted and 25.40% for total daughter numbers. The reason for this is unknown. The experiment will be repeated in 2001.

Table 3.1. Comparison of crowns dipped in BAP to control (no BAP).

Treatments	# Rooted	# Unrooted	Total Daughters	# daughters per mother
<i>Control</i>	40.75	14.25	55	11
<i>BAP</i>	24.75	31.25	56	11.1
Statistical Significance	**	ns	ns	
CV%	15.44%	49.12%	25.40%	

2) 2001 study, Saskatchewan Irrigation Diversification Centre, Outlook, SK

The site for this study was located at SIDC, in Outlook, SK. Before the crop was established, soil samples were taken to determine the N,P,K and S status. Soil nutrient levels were treated as previously described. Planting of 'Camarosa' strawberry crowns occurred on May 29th, 2001 in a RCBD.

The 2000 season provided high CV values and therefore treatments of 250mg/L of BAP (benzylaminopurine) plus a surfactant Tween 20 at 0.012% or distilled water and Tween 20 at 0.012% (control) were repeated in 2001 with an increased number of sub-samples. Each treatment consisted of four replicates of twenty plants each. Plants were treated with either solution by dipping for a ten-second duration and immediately planting into the field. All crowns were planted using a 30cm inter-row spacing and 100cm between row spacing and cultural practices as per the previous year. The number of mothers that survived the planting process were recorded one month later. The number of rooted and unrooted crowns per plant were recorded at the time of harvest.

Results

Harvest occurred on the 26th of September, 2001. Plants were dug using a small-modified potato harvester. Plants were placed into large plastic garbage bags and taken to the Horticulture Field Lab at the University of Saskatchewan for processing. There was a significant ($p \leq 0.05$) difference in the number of total daughters and total daughters per mother produced under the control treatment with no hormone (Table 3.2). This is consistent with year 2000 results. Crowns planted in spring, 2001 had also been in transit for two weeks prior to planting and thus were stressed at the time of delivery. It is believed that the condition of the crowns in conjunction to the added stress of the hormone solution was detrimental to the growth and crown development and may have contributed to the reduced number of daughters/ mother were produced.

Therefore, crown dipping into BAP hormone treatment is not recommended at this time.

Table 3.2. The effect of BAP (benzylaminopurine) whole crown dipping on daughter production in 'Camarosa' strawberry crowns.

Treatments	Marketable Daughters	Marketable Size without roots	Unrooted Daughters	Total Daughters	Total Daughters/Mother
<i>BAP</i>	20.29	11.79	13.62	45.71	6.40
<i>Control</i>	28.46	17.96	17.37	63.79	8.78
Statistical Significance	ns	ns	ns	*	*
LSD				11.47	2.07
CV%	25.79%	40.52%	47.18%	11.52%	15.03%

- ns is no significance; * and ** = $p \leq 0.05$ and $p \leq 0.01$, respectively

*Averages are based on the number of surviving mothers

IV) One Year vs. Two Year Production Cycle

This study determined the differences between the production of crowns in the first year of growth versus the second year. In the first year of production, mother crowns typically produce 5-8 daughter crowns. By contrast, in the second year, the same mother crowns will produce a significantly higher number of around 15 daughter crowns. The following three scenarios will be evaluated: a) harvest daughter crowns in the first year and leave mother crowns in the field for second year production, b) overwinter daughter crowns and harvest daughters produced in year two, c) harvest all daughter and mother crowns in the first year (control). In addition, fruit yield in California based on 1st year and 2nd year daughter plants were compared. Finally, Saskatchewan field 'Camarosa' fruit yield and quality were evaluated in the second year (courtesy, Tom Ward).

a) Harvesting Daughters & Leaving Mothers

This treatment will test the feasibility of planting mother crowns in the spring, harvesting the daughters produced in the fall of the same year, leaving the mother plants and allowing the mother plants to runner and produce daughter plants for a second season.

On May 16th, 2000, 20 strawberry plants for each of the four replicates were planted at our site south of Saskatoon (Lat. 52° 07'N, courtesy of Dr. Karen Tanino, Saskatoon, SK.). Eighty plants were split into 4 replicates of 20 plants each. The soil was a sandy loam with a pH of 7.8, which is conducive to strawberry production. Soil tests performed by Enviro-Test Agricultural Services indicated that the soil was deficient in nitrogen and phosphorous with marginal amounts of sulphur. Nitrogen and phosphorous levels were brought up to 110 lb/ac with 22 lb./ac of sulphur.

This plant material did not overwinter. In mid-October of last year (2000) the plants experienced a deep frost (-10°C). Deer damage had occurred prior to this frost whereby the leaves were all removed and thus the plants were more susceptible to the low temperature. Plants were still covered with straw mulch in late October to facilitate survival, however, many mother crowns were lost. According to Turner *et al.* (1993) mother plants are consistently less hardy than daughters in field conditions. Turner *et al.*

(1993) also suggests that mother crowns covered with mulch such as straw prior to a deep frost may enhance hardiness of mother crowns. In this study, the deep frost occurred prior to mulch application.

To provide some information regarding this treatment, overwintered plants at La Ronge, SK. from previous research were used. Daughter plants were removed in the spring of 2001 and two rows of 10 mother plants each were allowed to runner and produce daughters for data collection.

Results

Strawberry crowns were harvested on the 25th of September 2001. Statistical analysis could not be performed with other studies due to the differences between locations and original plant numbers, therefore general observations will be discussed. The number of marketable and unmarketable crowns were counted for each of the rows and averages were calculated (Table 4.1).

Table 4.1. Total number of 2nd year daughters produced from ten overwintered mothers with daughters removed in the first year in La Ronge, SK.

Treatments	Row	Marketable Daughters	Unmarketable	Total Daughters	Total Daughters/Mother
<i>Mothers with daughters removed in the 1st year.</i>	1	110	235	345	34.5
	2	73	102	175	17.5
<i>Mean</i>		91.5	168.5	130	13.0

From this data is difficult to determine how many daughter crowns may be produced by over-wintering mother crowns. The La Ronge area had considerable variation in the soil textures from one row to the next. The second row was in an extremely sandy location, while those in row 1 were in a loam and nutrient rich area. The differences in the soil textures were too great to provide a good average number of

daughters produced per mother. Nevertheless, 13 daughter crowns per mother is far higher than the normal average number of daughter crowns produced in year 1.

b) Harvesting Daughter Crowns in Year Two

This treatment tested the feasibility of planting crowns in the spring, over-wintering the daughter's in the field and then digging the second year daughter's in the fall of the second year.

This study was initiated as a side test in 1998. A part of the plot from 1998 were divided into four sections consisting of 20 mother crowns per section. Daughters were counted within each section to determine how many daughters per mother were produced in 1998. The area between the two rows per section were then tilled to allow the mother crowns to produce runners in 1999. The number of daughter crowns were counted at the time of harvesting to yield the following data (Table 4.2).

Table 4.2. First Year vs. Second Year Mother Plants and the Number of Daughter crowns produced.

	# Daughters/Mother 1998	# Daughters/Mother 1999	Difference (%)
Section #1	4.7	7.9	+68%
Section #2	6.7	8.1	+20%
Section #3	4.8	7.3	+52%
Section #4	7.9	7.1	-11%

The number of daughter crowns increased in all sections except section #4. This could have been due to a difference in the pH of the soil or soil type since it varies greatly at the La Ronge site. Weed problems the following season may also have caused a decrease in the vigor of the mother crowns.

In 2000, this treatment was planted at the Saskatoon location, however the plant material did not overwinter. In mid-October, 2000 the plants were exposed to -10°C. Deer damage had occurred prior to this frost whereby the leaves were all removed and

the plants were more susceptible to the low temperature. Plants were still covered with a straw mulch in late October to facilitate survival. While many mother plants were lost, sufficient numbers of daughters overwintered to provide a comparison with spring planted daughters. This result is consistent with Turner *et al.* (1993) where mother crowns were less hardy than daughter crowns under field conditions. These 100 overwintered daughters were allowed to runner and second year daughters were evaluated. Data consisted of the number of rooted, unrooted daughters produced in the second season of growth (Table 4.3). In 2002, the number of marketable rooted and unrooted daughters were evaluated based on the 2nd year of growth. While the average number of daughter crowns from the Outlook area has been approximately 8 daughters per mother, in the second year, that number increased to 12 daughters per mother (Table 4.4). In addition, root growth is generally greater on 2nd year daughter plants (Fig. 4.1).



Fig. 4.1. Differences in root growth between a 1st year and 2nd year daughter crowns.

Table 4.3. Number of daughters produced from 100 new plants versus 100 over-wintered daughter plants with the mothers removed in Saskatoon, SK.

Treatments	Marketable Daughters	Unmarketable Size with roots	Unrooted Daughters	Total Daughters	Total # Daughters/ Mother
<i>Daughter Crowns in Year Two</i>	225	220	245	690	6.90
<i>Daughter Crowns in Year One</i>	88	119	74	281	2.81

Table 4.4. Number of Rooted and unrooted marketable 2nd year daughter crowns in Outlook, SK based on 10 plants per replication with 4 replications, 2002

# rooted marketable daughter crowns	# unrooted marketable daughter crowns
22 ± 3.16	101 ± 3.36

Table 4.5. Summary of marketable strawberry fruit yield and comparison between California-sourced and Saskatchewan-sourced strawberry crowns.

Fruit Production Year		Source of Crowns	Marketable Yield kg/ha (lbs/acre)			
California	Location of Fruit Production		Jan. + Feb.	+/- %	Total	+/- %
2002	B&E Farms, Orange County, CA	Lassen Canyon, CA	7,373 (6,564)		9,124*** (8,124)	
		Saskatoon, SK (1 st year daughters)	5,747 (5,116)	- 28.3%	8,881 (7,907)	-2.7%
		Saskatoon, SK (2 nd year daughters)	6,400 (5,698)	- 15.2%	10,970 (9,767)	+20.2%

+/- represents the percentage above or below California-sourced crowns.

***Fruit yield to April 11.

Although both 1st and 2nd year daughter crowns initially lagged behind California-sourced 'Camarosa' crowns, by the end of the season, the 2nd year daughter crowns provided 20% higher marketable yield compared to California-grown crowns (Table 4.5).

c) Fruit yield and fruit quality of Saskatchewan-grown 'Camarosa'

Tom Ward incorporated 'Camarosa' into his cultivar trials which examined 39 Day-neutral and June-bearing cultivars for fresh and frozen fruit quality (physical fruit appearance, colour, fruit texture, hollow core, size), yield, fruiting period, and sensory evaluation. For further information, see "Testing Program for Adaptation of New Strawberry Cultivars for Saskatchewan", ADF # 97281. In general, 'Camarosa' ranked high in terms of texture (hardness) and was moderate in terms of insect, disease, stand, hardiness and runnering ability. Sensory evaluation ranking varied widely between years from 3rd to >10th out of 19 cultivars (Table 4.6).

**Table 4.6. Relative ranking of 'Camarosa' in Tom Ward's cultivar evaluation trial
(evaluated out of 19 June bearing cultivars)**

Trait	Ranking	
	Year 2000	Year 2001
Total Yield	5 th out of 11	12 th out of 14
Marketable Yield	85% of total yield	85% of total yield
Texture, hardness	1 st out of 19	1 st out of 19
Sensory Evaluation (fresh taste)	> 10th	3rd
Colour	9 th out of 19	8th
Aroma	>10 th	4th
Sweetness	> 10th	2nd
Acid	> 10th	3rd
Overall appearance, good dark colour		
Size	medium	medium
Insect damage	moderate	moderate
Disease damage	moderate	moderate
Stand	moderate	moderate
Hardiness	moderate	moderate
Runnering ability	moderate	moderate

d) Agri-Arm Spoke sites

Several Agri-arm spoke sites planted crowns in May, 2003. These included locations at: St. Louis; Swift Current; Scott; Canora and Redvers, SK. There was significant deer damage at the Scott and Swift Current locations which made harvesting impossible. The crowns at the St. Louis location did not grow well which may have been caused by moisture stress. Two locations were harvested: Canora and Redvers. Crown numbers were higher at Canora compared to Redvers with an average of 8.52 daughters per

mother (Table 4.7). At Redvers, there were 2 distinct sections of the plot which appeared to cause a moisture stress gradient (Table 4.8, possibly due to surface root competition from a row of Scotch pine). If these locations are re-planted, the use of greenhouse plugs or tissue-culture-based plugs is advised to increase daughter numbers. Alternatively use of Remay covers or 2nd year daughters could be produced.

Table 4.7. Number of runners and marketable 1st year daughters in Agri-Arm sites, 2003. Data represents mean of 10 mother crowns with 6 replications

Location	# runners	# marketable daughters
Canora	6.87 ± 2.63	8.52 ± 3.17
Redvers	5.27 ± 1.50	6.22 ± 3.19

Table 4.8. Number of daughters based on location within a plot at Redvers in 2003. Section A is located close to a row of Scots pine. Section B is located away from the pine. Data based on 10 plants per replication with 6 replications.

Section	# runners	# marketable daughters
A	1.75 ± 1.61	0.67 ± 1.14
B	5.27 ± 1.50	6.22 ± 3.19

e) Date of planting effect on yield

This data is from Brenda and Loren Lange's location near Good Soil, SK.
 Data taken on: September 8, 2000 based on 2 plantings: 1) early planting on May 20, 2000 of 85 crowns; 2) Late planting on May 26th of 128 crowns. Fertility: Brenda initially fertilized with 1:1 parts 30-10-10 and 7-7-0 (blood and bone meal). She then watered the first planting 3 times during the season with Miracle Grow 15-30-15 (diluted according to package instructions) and 2 times for the late planting.

In a preliminary experiment, even a one week planting advancement in May resulted in an increase in number of rooted daughters by September of that year (Table 4.9). The one week earlier planting had a higher runner and rooted daughter crown number. April plantings are encouraged since strawberry crowns can resist light frosts.

Table 4.9. Preliminary data on date of planting on daughter crown yield at Good Soil, SK, 2000.

Planting Date	Rep	# Runners/5 mother plants	# rooted crown/5 mother plants	# unrooted crowns/5 mother plants
May 20	1	38	14	72
	2	47	16	54
	3	63	21	37
Mean # per mother plant		9.8	3.4	10.8
May 26	1	43	6	45
	2	30	10	29
	3	39	9	20
Mean # per mother plant		7.4	1.6	11.2

V) Fertility Trial

The objective of this study was to evaluate the effect of nitrogen and phosphorus in a factorial experiment on subsequent runner and crown production in Saskatchewan with 'Camarosa'. Specific nutrient management practices are required for individual cultivars as strawberries are grown under widely different climatic conditions throughout the world (May *et al.*, 1990). It is therefore essential for Saskatchewan strawberry crown growers to have a recommendation made available to them to facilitate proper growth and profitable returns.

Strawberry nutrient recommendations provided by Enviro-Test Agricultural Services in Saskatoon, Saskatchewan suggest that the available soil nitrogen levels be brought up to 100-110 lbs./ac and phosphorous levels to 90-95 lbs./ca. Past studies have indicated these nutrient levels only produce 5-7 daughters per mother crown. These levels are considered unacceptable as strawberry crowns in Ontario produce over 20 daughters per mother crown. Therefore, new fertilizer recommendations are being tested to improve runner production for strawberry crown producers in Saskatchewan. This study consists of four treatments of four replicates each for 100 lbs./ac, 150 lbs./ac, 200 lbs./ac and 250 lbs./ac of nitrogen fertilizer.

1) Year 2000 results, Pike Lake location

Ten crowns for each of the four replicates per treatment were planted on the 16th of May, 2000. Prior to planting, each treatment area was fertilized with its respective level of nitrogen. Plants are being watered on a regular watering regime utilizing an overhead watering system on a pivot. To encourage runner and crown production, flower buds were removed as required. The treatment effect on crown production was evaluated by determining the number of runners per plant and rooted and unrooted crowns per plant at time of harvest.

Soil tests during and after treatments were conducted to estimate the available nutrients. Response measurements will include runner and crown production.

Results

The treatment of 200 lbs./ac of nitrogen produced significantly more unrooted and total daughters per mother (Table 5.1).

Table 5.1. Effect of nitrogen dose on 'Camarosa' daughter production, Pike Lake, 2000.

The effect of various fertilizer regimes on 'Camarosa' strawberry crowns at Pike Lake, SK 2000			
Treatments	# Rooted/Mother	# Unrooted/Mother	Total Daughters/Mother
100 lbs./ac N	3.45	3.10 b	6.55 b
150 lbs./ac N	4.73	2.25 b	6.98 b
200 lbs./ac N	5.58	6.10 a	11.69 a
250 lbs./ac N	5.01	1.60 b	6.61 b
Statistical Significance	ns	*	*
CV%	36.56%	55.97%	74.40%

* denote significance at 0.05

Results

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Table 5.1. Effect of nitrogen dose on 'Camarosa' daughter production, Pike Lake, 2000.

The effect of various fertilizer regimes on 'Camarosa' strawberry crowns at Pike Lake, SK 2000.			
Treatments	# Rooted/Mother	# Unrooted/Mother	Total Daughters/Mother
100 lbs./ac N	3.45	3.10 b	6.55 b
150 lbs./ac N	4.73	2.25 b	6.98 b
200 lbs./ac N	5.58	6.10 a	11.69 a
250 lbs./ac N	5.01	1.60 b	6.61 b
Statistical Significance	ns	*	*
CV%	36.56%	53.97%	25.42%
*denotes significance at $p \leq 0.05$			

2) Year 2001, Saskatchewan Irrigation Diversification Centre, Outlook

The site was located at SIDC in Outlook, Saskatchewan. Twenty plants per replicate per treatment were planted on the 29th of May 2001. Prior to planting, each treatment area was fertilized with its respective level of nitrogen. Plants were watered on a regular watering regime utilizing an overhead watering system. To encourage runner and crown production, flower buds were removed as required. The treatment effect on crown production was evaluated by determining the number of rooted and unrooted crowns per plant at time of harvest.

Results

Harvest occurred on the 27th of September 2001. Plants were dug using a small-modified potato harvester. Plants were placed into large plastic garbage bags and taken to the Horticulture Field Lab for processing. There was a significant difference ($p \leq 0.01$) between the number of marketable daughters produced by 100 and 200 lbs./ac of N compared to 150 and 250 lbs./ac of N (Table 5.2, Fig. 5.1). Significant differences were also noted between 100, 150 and 200 lbs./ac of N compared to 250 lbs./ac of N for total daughters at a $p \leq 0.05$ significance level and total daughters per mother at a $p \leq 0.01$ significance level. This would indicate that 250 lbs./ac of N could be detrimental to plant development. When considering the CV%, they are quite high, ranging from 15.9% to 46.89%. Problems arose in the test plot due to the variation of weed development within the plot. Previous research conducted in the area had caused a reduction in the weeds present, however, the test plot for this study had been planted unknowingly on half weed controlled land and half not resulting in a weed problem for 1/3 of the replicates. This could have caused variations in the numbers of daughters produced. Previous research conducted in 2000 suggested that 200 lbs./ac of N was the most beneficial. In 2001, this treatment still had the highest numbers of daughters produced and the significance may be hidden due to the high variation.

Table 5.2. The effect of various fertilizer regimes on 'Camarosa' strawberry crown production, Outlook SK 2001.

Treatments	Marketable Daughters	Marketable Size without roots	Unrooted Daughters	Total Daughters	Total Daughters/Mother
100 lbs./ac N	112.10 a	53.89	37.35	203.3 a	11.55 a
150 lbs./ac N	85.92 b	40.43	61.92	188.3 a	10.74 a
200 lbs./ac N	113.34 a	68.84	35.59	217.8 a	12.51 a
250 lbs./ac N	51.64 c	33.83	43.14	128.3 b	6.90 b
Statistical Significance	**	ns	ns	*	**
LSD	22.46	-		51.07	2.69
CV%	15.90%	47.89%	33.27%	17.79%	16.64%

- ns is no significance; * and ** = $p \leq 0.05$ and $p \leq 0.01$, respectively

*Averages are based on the number of surviving mothers



Figure 5.1. 'Camarosa' crowns treated to 100 (left) and 200 (right) lbs./ac of nitrogen

VI) Herbicide Trial

A large seasonal labor force is required for crown production in part because weeding is normally conducted by hand. A possible method to decrease the cost of labor is to use a herbicide containing trifluralin to kill any pre-emergent weed seedlings. Treflan E.C.™ was chosen as the trifluralin source for this study and is currently registered for use on strawberries. Treflan E.C.™ is a selective liquid herbicide containing 480g/L of active ingredient. It is used for pre-plant soil incorporated weed control in many field crops, vegetables and ornamentals. Treflan E.C.™ is registered for use on strawberry crowns as a spring application. Planting can occur immediately following the herbicide's application. Treflan E.C.™ is usually used on fields intended for U-pick strawberry operations. The concern in using this product for crown producing fields is the potential loss in the number of rooted daughters. Trifluralin inhibits growth of root and shoot tips as plants germinate and begin to emerge. If the shoot portion of affected plants escapes to the soil surface, lateral and secondary root growth continues to be inhibited, which may result in a less vigorous plant (Guide to Crop Production 2000, Saskatchewan Agriculture and Food). Due to the herbicide's action, the concern is that the new roots forming on the daughter plants may be killed therefore decreasing the number of viable daughters. This would however, also decrease the amount of weeds within the fields and thereby reduce labor costs.

1) Year 2000, Pike Lake location

The site for this study was located twenty minutes south of Saskatoon near Pike Lake, Saskatchewan. Chemical application and planting occurred on the 19th of May, 2000

Three treatment levels of Treflan E.C. [™] were used: a) the recommended rate (as per chemical packaging) of 2.7 L/ha for loam soils (Table 6.1), b) double the recommended rate and c) no chemical applied (control). Each treatment consisted of four replicates of ten plants per replicate. Prior to planting, the plot area was treated with its respective chemical rate and worked in following the chemical guidelines. Plants were immediately planted following the chemical application. Plants are being watered on a regular watering regime utilizing an overhead watering system on a pivot. To encourage runner and crown production, flower buds were removed periodically. Runners were hand set as required. The treatment effect on crown production was evaluated by determining the number of runners per plant and rooted and unrooted crowns per plant at time of harvest.

Table 6.1. Recommended Rates of Treflan E.C. [™] (Litres per Hectare)

Crop	Soil Zones and Soil Organic Matter	Soil Texture		
		Light	Medium	Heavy
		Sand	Loam	Silty Clay
		Sandy Loam	Silt Loam Silt Sandy Clay Loam	Loam Clay Loam Silty Clay Clay
Strawberries	Brown, dark	1.7 L/ha	2.3 L/ha	
Saskatoon berries	brown or black 2-6% O.M.			
Spring Application Only	Black or deep black 6-15% O.M.	2.3 L/ha	2.3 L/ha	

* Excerpt taken from the Dow AgroSciences Treflan E.C. [™] chemical brochure.

[™] Trademark of Dow AgroSciences LLC

Results

Treflan applied at the recommended rates increased total daughter numbers per mother over the control treatment (Table 6.2).

Table 6.2 Treflan dose response on strawberry crown production, Pike Lake, 2000.

Comparison of various rates of Treflan* on strawberry crown production in 2000 at Pike Lake, SK.			
Treatments	# Rooted/Mother	# Unrooted/Mother	Total Daughters/Mother
<i>Recommended Rate</i>	6.64	3.30	9.94 a
<i>No Treflan E.C.[™] (Control)</i>	4.39	3.20	7.60 a b
<i>Twice the Rate</i>	3.54	2.58	6.12 b
<i>Statistical Significance</i>	ns	ns	*
<i>Lsd</i>		2.77	3.18
<i>CV%</i>	46.60%	55.37%	21.42%

* Trademark of Dow AgroSciences LLC

2) Year 2001, Saskatchewan Irrigation Diversification Centre, Outlook, SK

The site for this 2001 study was located at SIDC in Outlook, Saskatchewan. Chemical application and planting of 'Camarosa' strawberry crowns occurred on the 7th of June 2001. Three treatment levels of Treflan E.C. [™] were used: a) the recommended rate (as per chemical packaging) of 2.3 L/ha for loam soils (Table 6.3), b) double the

Results

Treflan applied at the recommended rates increased total daughter numbers per mother over the control treatment (Table 6.2).

Table 6.2 Treflan dose response on strawberry crown production, Pike Lake, 2000.

Comparison of various rates of Treflan® on strawberry crown production in 2000 at Pike Lake, SK.			
Treatments	# Rooted/Mother	# Unrooted/Mother	Total Daughters/Mother
Recommended Rate	6.64	3.30	9.94 a
No Treflan E.C. (Control)	4.39	5.20	7.60 a b
Twice the Rate	3.54	2.58	6.12 b
Statistical Significance	ns	ns	*
Lsd		2.77	3.18
CV %	46.60%	55.37%	21.42%
* Trademark of Dow AgroSciences LLC			

2) Year 2001, Saskatchewan Irrigation Diversification Centre, Outlook, SK

The site for this 2001 study was located at SIDC in Outlook, Saskatchewan. Chemical application and planting of 'Camarosa' strawberry crowns occurred on the 7th of June 2001. Three treatment levels of Treflan E.C.™ were used: a) the recommended rate (as per chemical packaging) of 2.3 L/ha for loam soils (Table 6.3), b) double the

recommended rate and c) no chemical applied (control). Each treatment consisted of four replicates of twenty plants per replicate. Prior to planting, the plot area was treated with its respective chemical rate and worked in following the chemical guidelines. Plants were immediately planted following the chemical application. Plants were watered on a regular regime utilizing an overhead watering system. To encourage runner and crown production, flower buds were removed periodically. Runners were handset as required. The treatment effect on crown production was evaluated by determining the number of runners per plant and rooted and unrooted crowns per plant at time of harvest.

Results

Harvest occurred on the 27th of September 2001. Plants were dug using a small-modified potato harvester, placed into large plastic garbage bags and taken to the Horticulture Field Lab for processing. Significant differences ($p \leq 0.05$) were only noted between the total number of daughters and total daughters per mother (Table 6.3). The control treatment with no herbicide application had significantly higher daughter numbers in both cases (Figs. 6.1, 6.2). No differences were noted between the recommended rate and twice the recommended rate. Year 2000 results suggested that the recommended rate of Treflan E.C. TM actually increased daughter production (Table 6.2). A possible explanation for this discrepancy was crown condition in 2001. Crowns received in 2001 had been held in transit for two weeks and were therefore already stressed prior to the application of the Treflan E.C. TM. As well, the plot area had a pH of 8.3 which is high for 'Camarosa'. This caused iron deficiency to occur, further stressing the plants. Even once this was rectified with iron chelate, the plants still appeared stressed. The control plants did not have the compounding affect of the herbicide and thus may have produced more daughter plants.

Table 6.3. The effect of Treflan E.C. TM on 'Camarosa' strawberry crowns.

Treatments	Marketable Daughters	Marketable Size without roots	Unrooted Daughters	Total Daughters	Total Daughters/Mother
<i>Recommended Rate</i>	16.08	9.81	12.94	38.83 b	3.871 b
<i>No Treflan E.C. TMControl</i>	34.49	28.45	22.74	85.68 a	8.12 a
<i>Twice the Recommended Rate</i>	18.18	13.49	13.32	44.99 b	4.22 b
Statistical Significance	ns	ns	ns	*	*
LSD	-	-	-	24.80	2.68
CV%	37.28%	30.45%	37.01%	26.92%	30.41%

- ns is no significance; * and ** = $p \leq 0.05$ and $p \leq 0.01$, respectively

*Averages are based on the number of surviving mothers

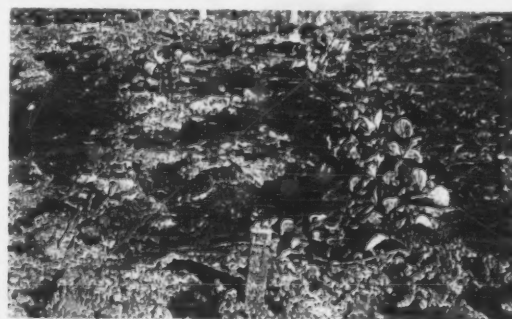


Figure 6.1. 'Camarosa' treated with Treflan E.C. TM at recommended rates (left) and twice the rate (right) in 2001.



Figure 6.2. 'Camarosa' crowns not treated with Treflan E.C. TM (control) in 2001.

VII) Fumigation Trial

The objective of this study was to test the effectiveness of a fumigant product in controlling soil-borne nematodes. Larson *et al.* (1995) found that even in the absence of identifiable pests or pathogens, soil fumigation improves runner plant production and quality. Hancock *et al.* (2001) supports these results by stating that fumigation enhanced all tested genotypes in terms of runnering, fruit size and yields. Chandler *et al.* (2001) also determined that overall crown productivity was substantially reduced by growing plants in soil that has not been fumigated prior to planting, even in the absence of lethal pathogens. These findings led us to believe that a soil fumigant may increase runner production for 'Camarosa' strawberry crowns produced in Saskatchewan.

Basamid® a granular soil fumigant (active ingredient Dazomet) was chosen due to ease of application and control of soil-borne nematodes, soil fungi and germinating weed seeds. It is suitable for fumigating open land and all types of seedbeds for nurseries and greenhouses (BASF Canada Inc. label information).

The site was located at SIDC in Outlook, Saskatchewan. Two treatments were tested – fumigant and no fumigant. Two weeks prior to planting, a granular soil fumigant Basamid® was applied to the treatment areas at the recommended rate of 4.25 kg per 100 sq. metres. On contact with moist soil, the fumigant breaks down and releases toxic gases, which spread throughout the air phase of the soil. Therefore, post treatment consisted of packing and watering the areas to form a surface crust and seal in the gases. On the 22nd of May 2001, the treated areas were rototilled to aerate the soil to remove all traces of toxic gases. Twenty plants for each of the four replicates per treatment were planted on the 29th of May 2001 in a RCBD. To encourage runner and crown production, flower buds were removed as required. Plants were watered on a regular watering regime utilizing an overhead watering system. The treatment effect on crown production was evaluated by determining the number of runners per plant and rooted and unrooted crowns per plant at time of harvest.

* Product of BASF Canada Inc.

Results

Harvest occurred on the 27th of September 2001. Plants were dug using a small-modified potato harvester, placed into large plastic garbage bags and taken to the Horticulture Field Lab for processing. No significant differences were noted between the two treatments (Table 7.1). Fumigation does not appear to be detrimental to daughter plant formation. Fumigation however did not enhance runner formation according to Larson *et al.* (1995). Possibly our soils are free of various pathogens that are present in the soils in Michigan where Larson *et al.* conducted their research.

Table 7.1. The effect of fumigation on 'Camarosa' strawberry plants.

Treatments	Marketable Daughters	Marketable Size without roots	Unrooted Daughters	Total Daughters	Total Daughters/Mother
<i>Fumigated</i>	85.71	57.39	53.75	196.8	11.33
<i>No Fumigation</i>	89.04	67.61	37.00	193.7	10.97
Statistical Significance	ns	ns	ns	ns	ns
CV%	28.05%	18.31%	33.27%	18.57%	18.55%

- ns is no significance; * and ** = $p \leq 0.05$ and $p \leq 0.01$, respectively

*Averages are based on the number of surviving mothers

High CV% in the analysis may have been due to poor plant material received and the compounding effect of iron deficiency.

VIII) Greenhouse plug production

Greenhouse-produced plugs have several advantages including:

a) Fitting into existing scheduling of greenhouse growers operations without added energy costs; b) Higher value per plant compared to field-produced plants (3 fold); c) Less risk of nematode infection; d) Reduced labour requirements for cutting and trimming of crowns in the fall. The disadvantages include: a) necessity of maintaining mother plants in the greenhouse for several months of the year; b) Higher shipping costs to California compared to field-grown bare root plants due to fewer plug plants per truckload; c) Limited market compared to field-grown bare root crowns.

In 2002-2003, the potential for greenhouse plug plant production was tested at the College of Agriculture, University of Saskatchewan greenhouses and plug plants were also produced at a commercial grower operation, Kelvin Mah of Floral Acres. In the fall of 2003, both greenhouse and Saskatchewan field-grown plants were 10 days to 2 weeks more advanced than other California-sourced crowns planted at the same time (Steve Ozawa, pers. Comm.). However, both plug plants and field-grown crowns became vegetative in growth habit for about 2 weeks. This delayed fruiting. In January, fruit was beginning to be picked from Saskatchewan-sourced crowns and this was 2 weeks delayed compared to California-sourced crowns. Nevertheless, fruit size, particularly on the greenhouse-grown plugs, was larger than other fruit produced in January, 2004. Fruit yield and size will continue to be evaluated through the fresh market season in California.

The following were assessed:

i) **Yield of daughter crowns in the greenhouse.**

Two light levels (approximately 350 $\mu\text{mol}/\text{m}^2/\text{s}$ and 700 $\mu\text{mol}/\text{m}^2/\text{s}$ PAR) at 2 bench spacings (close = 20, 6" pots/2.1 m^2) or wide (20, 6" pots/4.2 m^2). 'Camarosa' strawberry crowns (bareroot) were purchased from Norcal Nurseries, California, potted into 6" containers between May 10-12, 2002. Four replicates of 10 pots per replicate were placed into the 2 greenhouse wings (B1 and F) of the College of Agriculture Greenhouses, University of Saskatchewan. Runner and daughter numbers were assessed.

Results

Higher light levels was more effective to increase both runner and daughter number (Table 8.1). However, an interaction between light levels and wider spacing combined to produce the highest number of runners and daughter crowns per mother. Daughter yield increased from 2.6 daughters per mother under low light ($350 \mu\text{mol}/\text{m}^2/\text{s}$) and close spacing to 33.6 daughters per mother under higher light ($700 \mu\text{mol}/\text{m}^2/\text{s}$) and wide spacing.

Table 8.1. Number of runner and daughter crowns produced under 2 greenhouse light conditions (B1, lower light levels; F1, double light levels) and 2 pot spacings (close = 20, 6" pots/ 2.1 m^2) or wide (20, 6" pots/ 4.2 m^2).

Location	Runner # per plant		Daughter # per plant	
	Close spacing	Wide spacing	Close spacing	Wide spacing
B1 greenhouse	2.3 ± 2.17	3.75 ± 2.02	2.6 ± 2.72	4.7 ± 2.95
F1 greenhouse	6.55 ± 1.78	13.45 ± 3.48	6.1 ± 1.74	33.6 ± 9.00

ii) Production rate of daughter crowns under greenhouse conditions

The production cycle of daughter crowns from 6" potted mother crowns under greenhouse conditions was assessed. The spacing was "close" (as above), however, pots were lined up along one edge of the bench and therefore, light competition was reduced (Fig. 8.2). The number of first, second and third daughters were counted. Four hundred and fifty mother crowns were planted between May 10 – 12, 2002. Harvest of daughter crowns was taken on June 28 and July 22, 2002. Production of daughter crowns was higher on the second sampling, likely because by that time, mother crowns had become established in the pot (Figure 8.1). Once established, the

cycle of daughter crown production from mother plants can be as short as 3 weeks. Figs. 8.2 – 8.3).

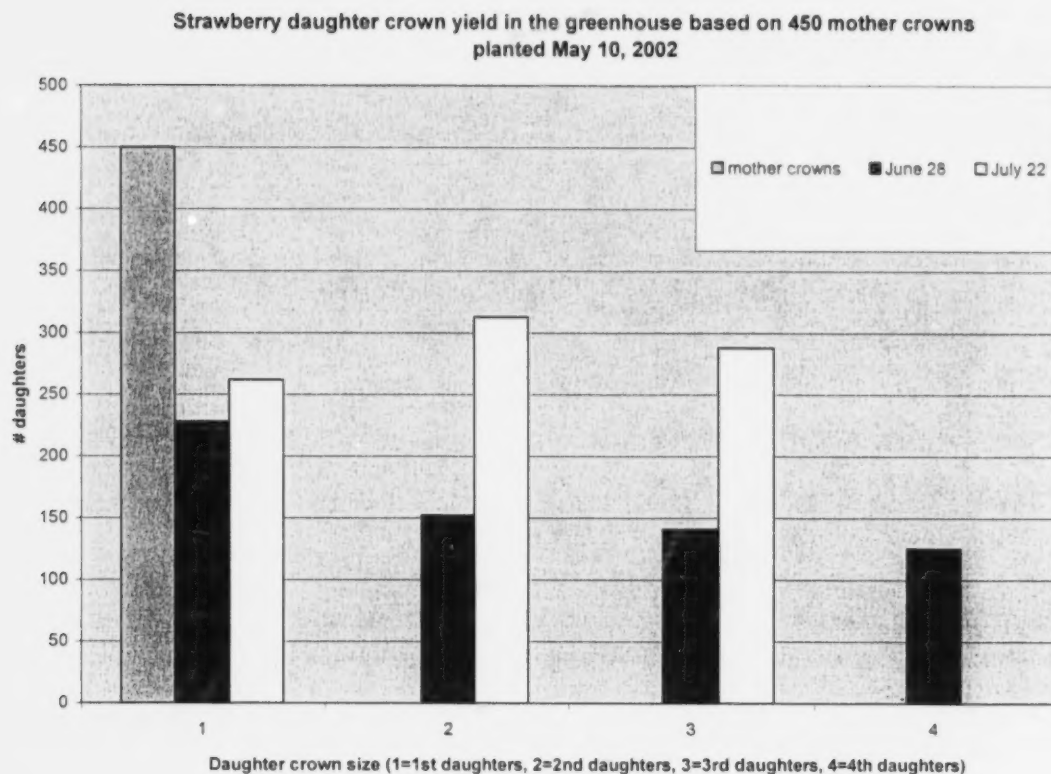


Fig. 8.1. Cycle of daughter crown production based on mother crowns grown in 6" pots under greenhouse conditions.

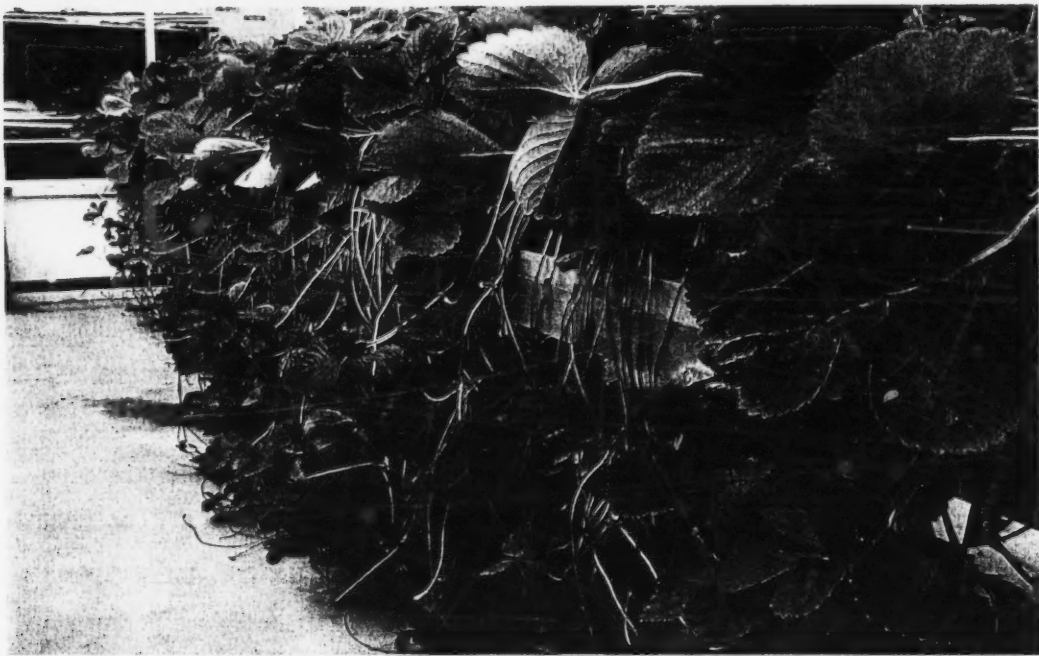
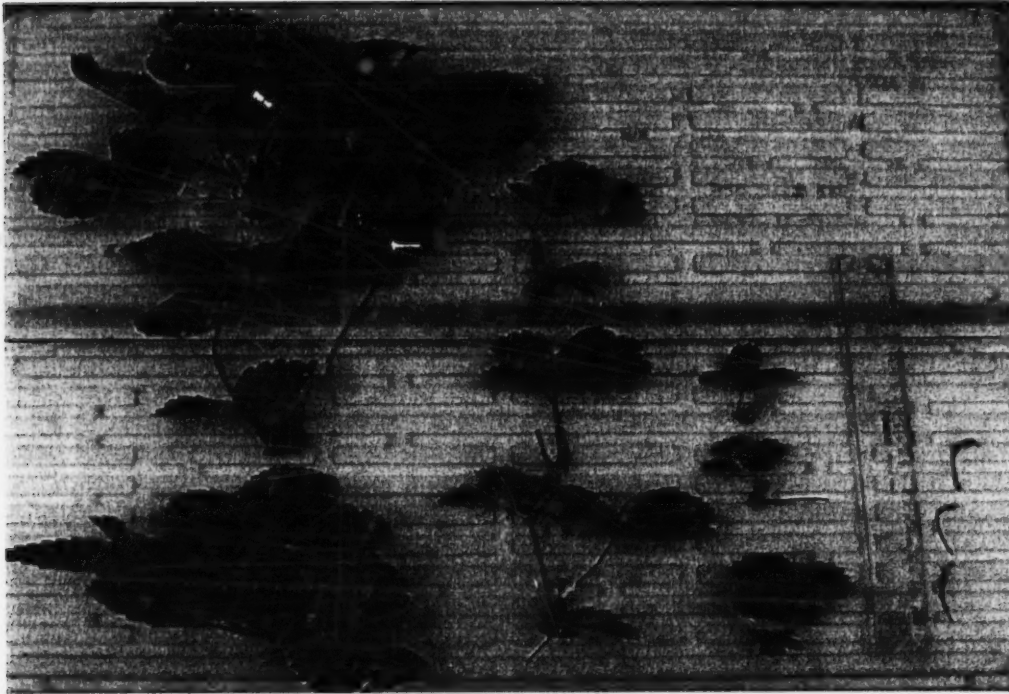


Fig. 8.2. Upper: first, second, third daughter and runner tips. Lower: runners in the greenhouse on June 28, 2002, 6 weeks after planting mother crowns into 6" pots.

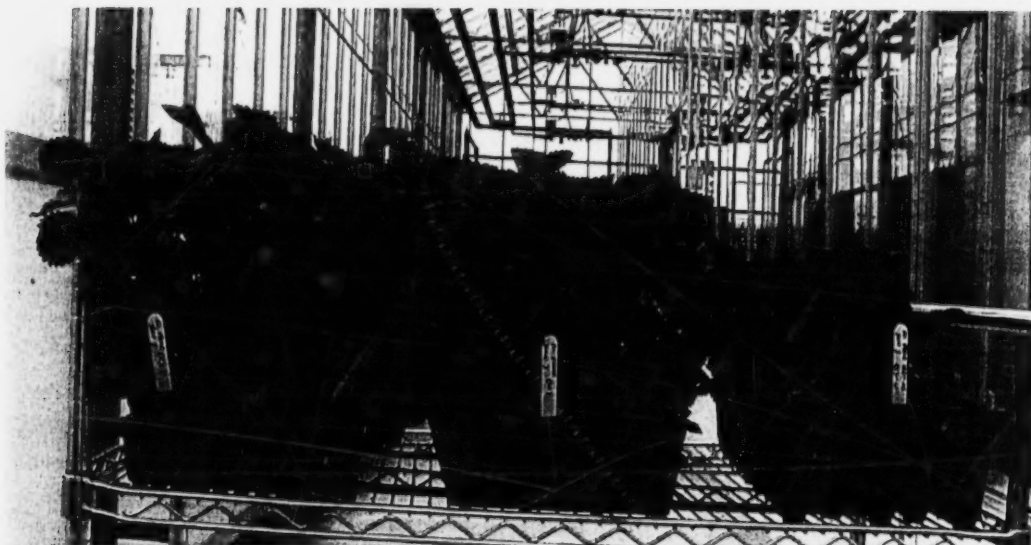


Fig. 8.3. Pot size effects on runnening of mother crowns planted into 2" compared with 6" containers. Lower: mother plants are the same age and planted at the same time.

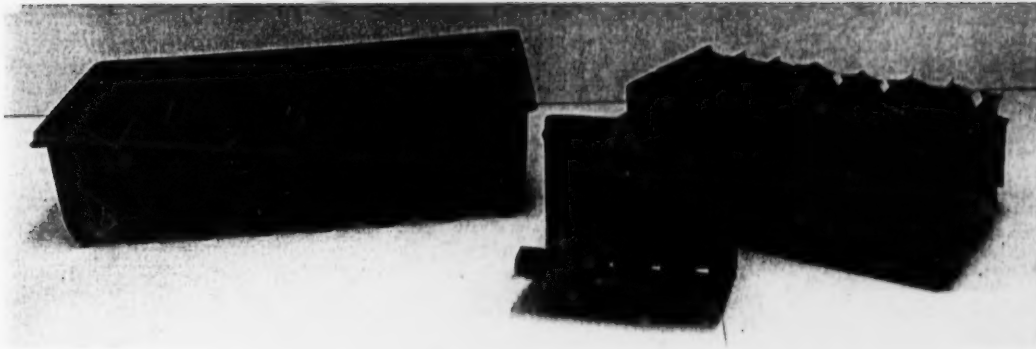


Fig. 8.4. Upper: sample containers of Spencer Lamair and tree seedling. Lower: root growth on plug plants 7 weeks old.

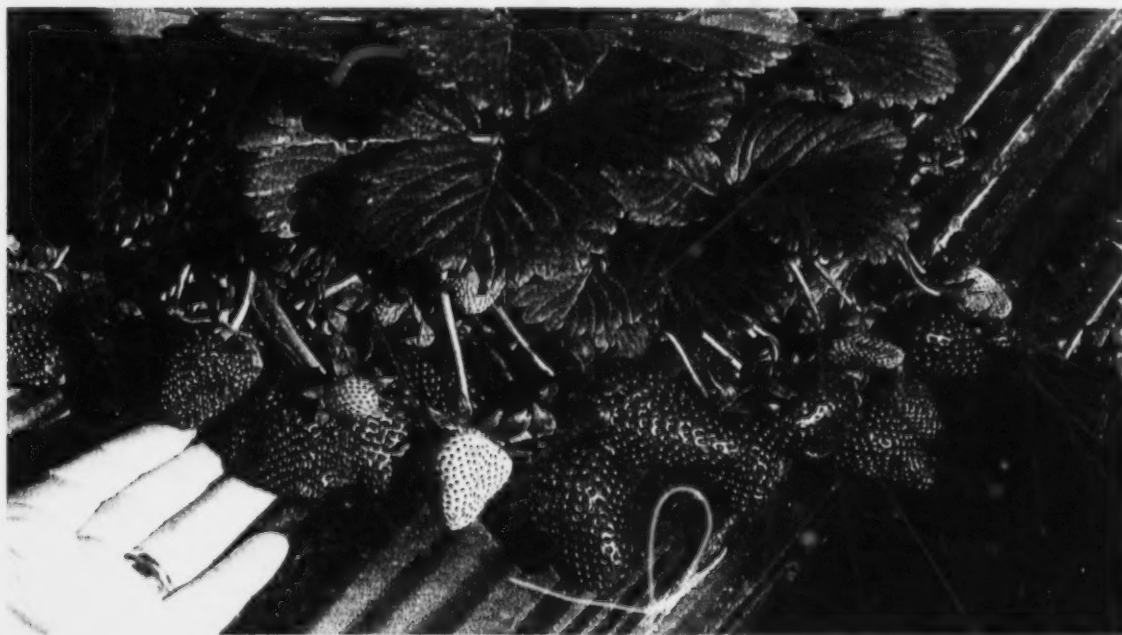


Fig. 8.5. 'Camarosa' fruit in April, 2002 at the B&E farms field plots in Irvine, California.



Fig. 8.6. Outlook location crowns planted in California at B&E Farms, Irvine, California, April, 2002.



Fig. 8.7. View of strawberry fields, Irvine, California. April, 2002.



Fig. 8.8. Upper: Bill Ito (left) and Steve Ozawa (right). Lower: Chas Nakama, Oxnard, California.



Fig. 8.9. Dr. Kirk Larsen, UC Davis at the South Coast Research Station, Irvine, CA. April, 2002.

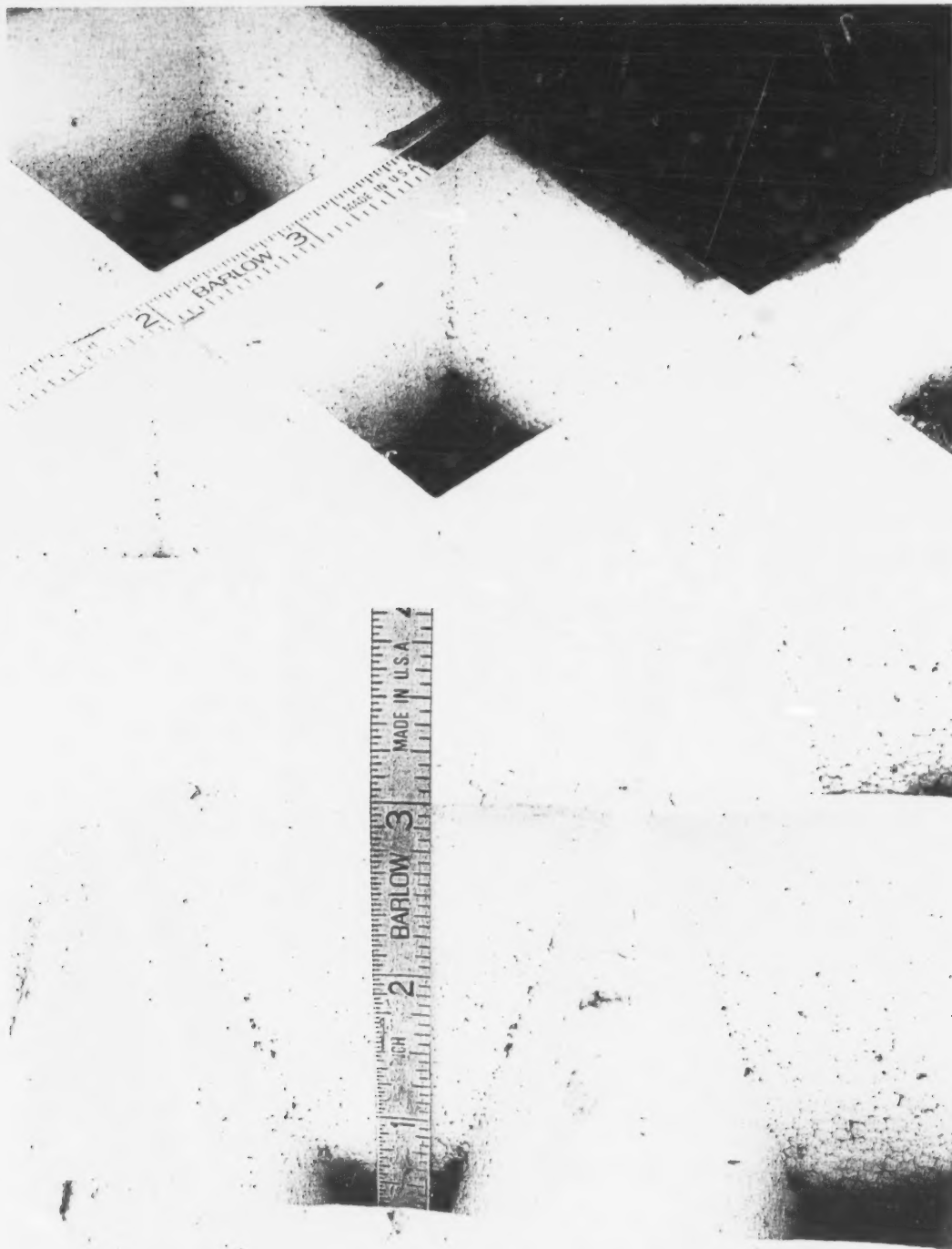


Fig. 8.10. Styrofoam plug trays used by California plug plant producers.

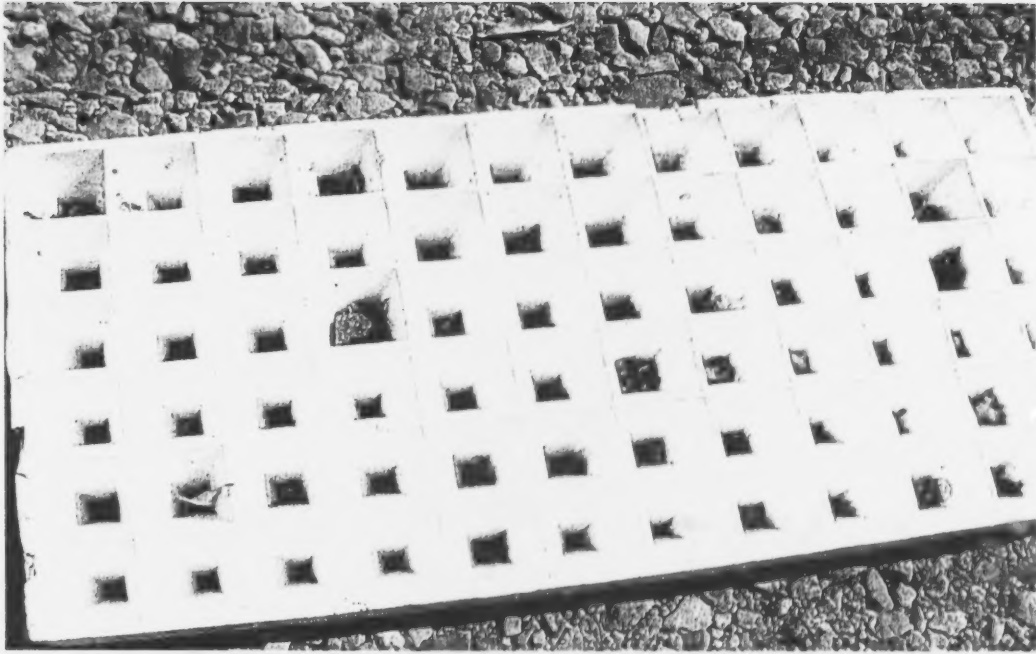


Fig. 8.11. Plug tray and media used by California plug plant producers



Fig. 8.12. Problem with plug plants in field: many split crowns, April, 2002.

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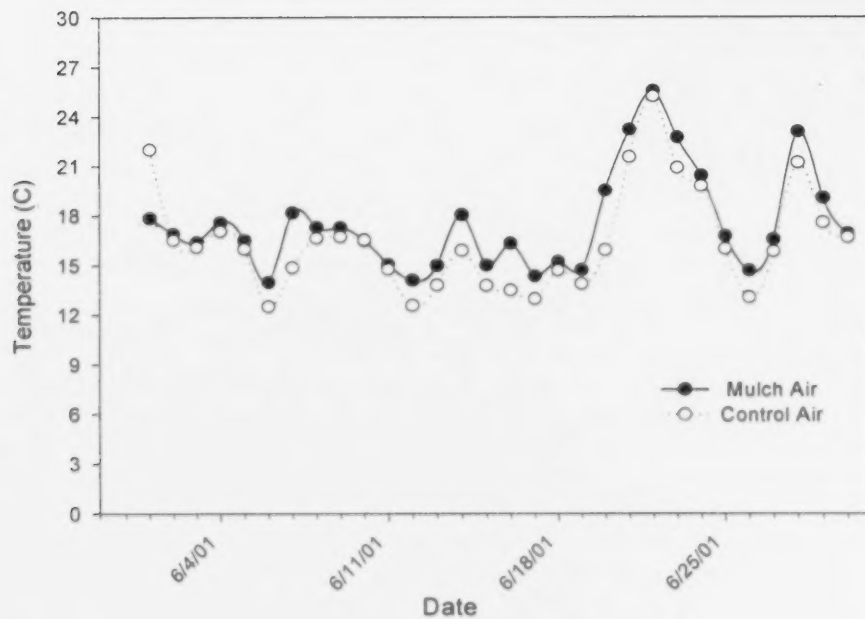


Figure A1. Mean daily air temperatures at crown level for June, 2001 under mulch (Remay) and control (bare ground).

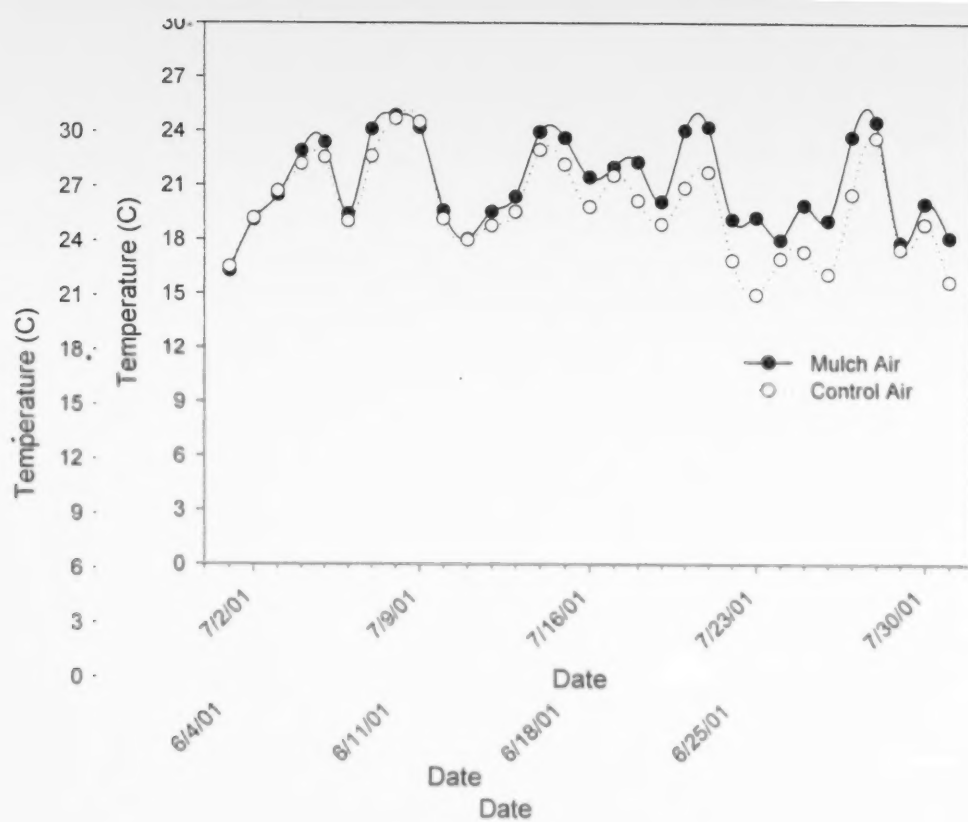


Figure A2. Mean daily air temperatures at crown level for July, 2001 under mulch (Remay) and control (bare ground).

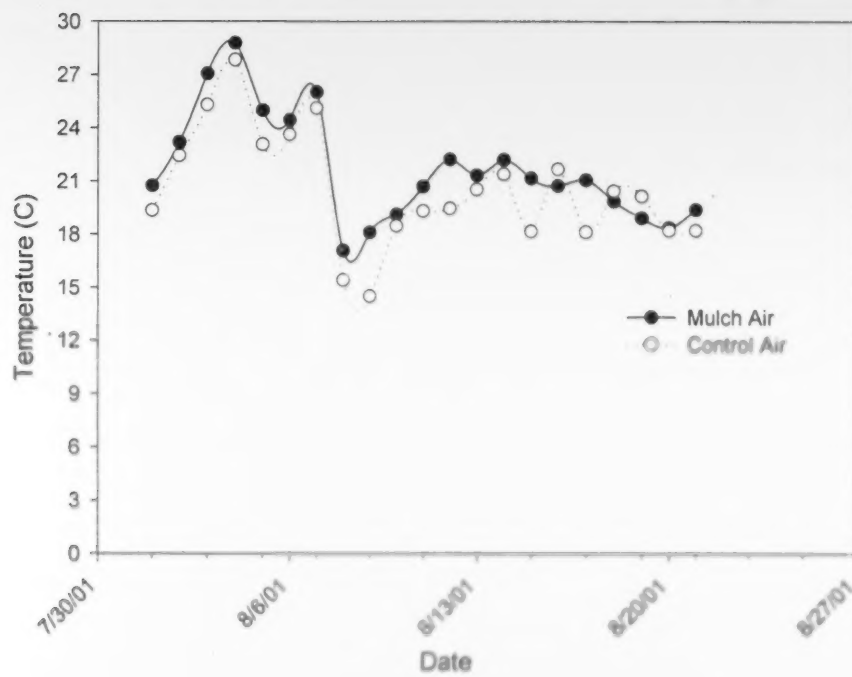


Figure A3. Mean daily air temperatures at crown level for August, 2001 under mulch (Remay) and control (bare ground).

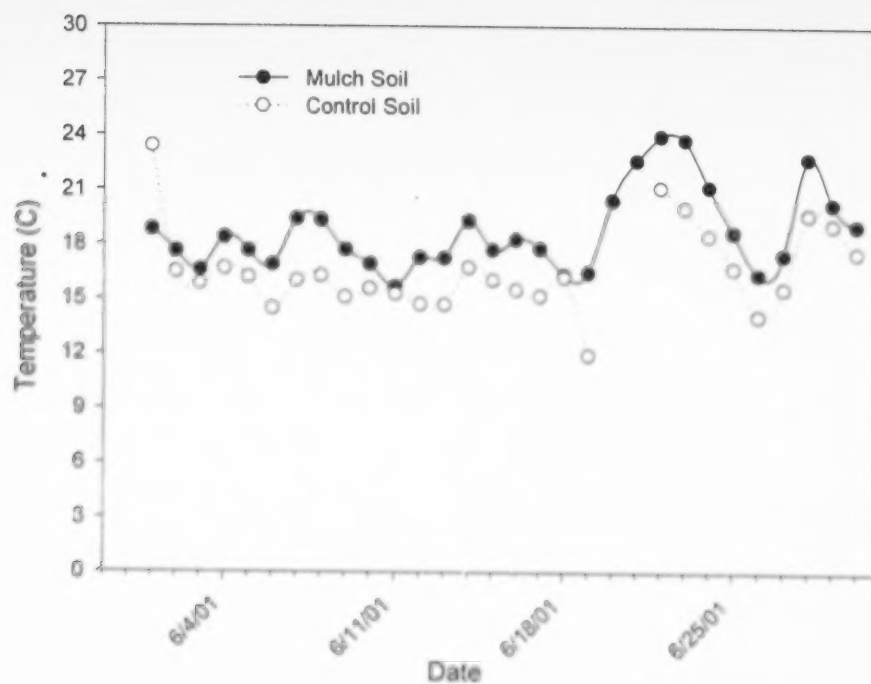


Figure A4. Mean daily soil temperatures at 7.5 cm depth for June, 2001.

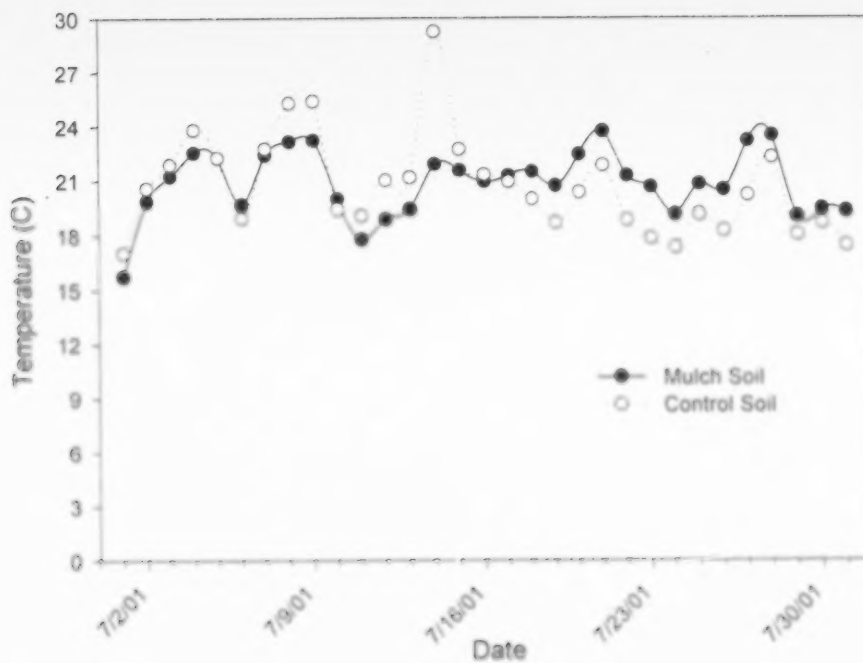


Figure A5. Mean daily soil temperatures at 7.5 cm depth for July, 2001.

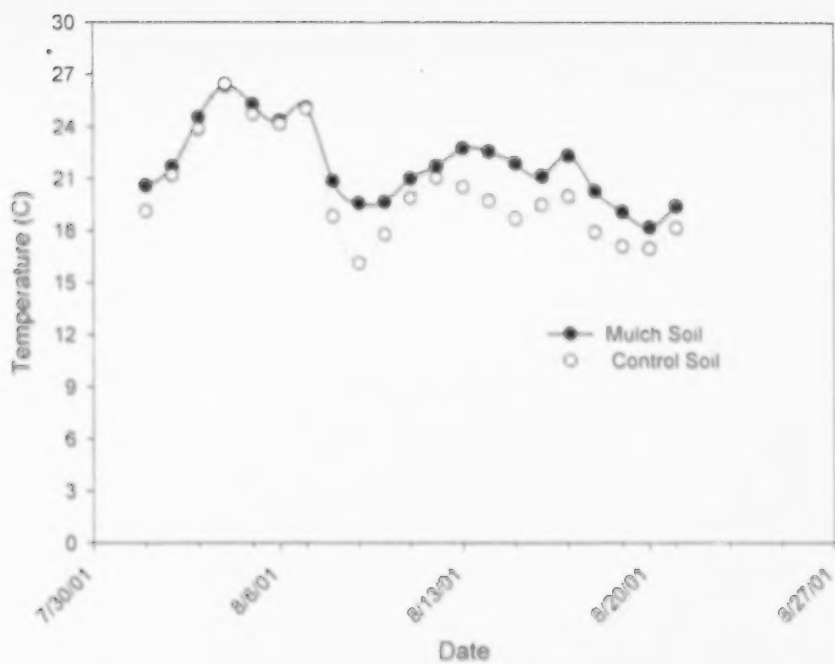


Figure A6. Mean daily soil temperatures at 7.5 cm depth for August, 2001.

